

## 5.—CONTRIBUTIONS TO THE MINERALOGY OF WESTERN AUSTRALIA—SERIES VI.

By EDWARD S. SIMPSON, D.Sc., B.E., F.A.C.I.

*Read 12th May, 1931; Published 25th June, 1931.*

### CONTENTS.

	Page
(1) Allanite, Woodstock	137
(2) Andalusite and Sillimanite, Ninghanboun Hills	138
(3) Cummingtonite, Ninghanboun Hills	140
(4) Dravite, Darling Ranges	141
(5) Gahnite, Greenbushes	144
(6) Gedrite, Bullsbrook	144
(7) Lechatelierite, West Popanyinning	145
(8) Pyrolusite, Coppermine Creek	147
(9) Stilbite, Gooseberry Hill	147

### (1) ALLANITE, WOODSTOCK, N.W. DIVISION.

In granite country on pastoral lease 5012 (part of Woodstock Station), at a point five miles S.S.E. of Trig. Station B4, several detrital specimens of allanite have been found on the outcrop of a pegmatite vein. The mineral is in black, glassy, sub-angular fragments, with a thin brown crust of weathering products, which also penetrate the mass in narrow veinlets. Occasional small scales of mica form inclusions in the masses or are attached to their surfaces. Thin sections under the microscope are transparent and isotropic, yellowish green in colour, with fine black inclusions, especially along a rectangular network of indistinct cleavages. Heated in a closed tube, the mineral gives off a little water, but does not change in colour, decrepitate or melt. Before the blowpipe thin edges melt and boil. The refractive index was determined by the immersion method to be 1.692 for the analysed powder in sodium light.

An analysis was made for me by Mr. D. G. Murray, A.A.C.I., with the following results:—

#### ALLANITE, WOODSTOCK.

SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	Ce <sub>2</sub> O <sub>3</sub>	La <sub>2</sub> O <sub>3</sub>	Di <sub>2</sub> O <sub>3</sub>	(Y,Er) <sub>2</sub> O <sub>3</sub>	ThO <sub>2</sub>	TiO <sub>2</sub>	
30.60	16.18	3.52	19.36	Nil	Nil	2.22	1.02	0.36	
FeO	MnO	CaO	MgO	(K,Na) <sub>2</sub> O	H <sub>2</sub> O —	H <sub>2</sub> O +	Total.	G.	N.
8.60	4.48	7.76	.46	Nil	.22	5.07	99.85	3.52	1.692

A careful search for lanthanum and didymium failed to reveal any trace of those metals, repeated treatment of the freshly precipitated rare earth hydroxides with saturated solution of bromine yielding no soluble hydroxides whatever. In this respect the Woodstock allanite appears to be unique, all the newer analyses quoted by Doelter \* showing oxides of these metals in quantities varying from 2.7 to 17.3 per cent.

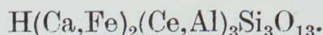
\* H.B. der Mineralchemie II. (2), 864-870.



The formula calculated from the analysis is :—



which is a hydrated modification of one of Nils Engstroms formulae, † viz. :



corresponding to the general formula for the Zoisite Group to which allanite belongs. Similar hydrated allanites are known from Norway and Sweden.

## (2) ANDALUSITE AND SILLIMANITE, NINGHANBOUN HILLS, S.W. DIVISION.

The Ninghanboun Hills, which lie about 25 miles east of Morawa in Lat.  $29^{\circ} 12'$  S., and Long.  $116^{\circ} 27'$  E., form the north-western shore of Weelhamby Lake, and are about three miles long by one mile or less wide, and at most 200 feet high. They rise out of the granite plateau which has a level here of about 850 feet above sea. Although physiographically insignificant, they present an almost complete microcosm of the Archaean rocks of the State. The centre and northern slopes consist of greenstones of various kinds, both massive and schistose, with jasper bars, quartz veins and pegmatite veins, the southern slopes of highly metamorphosed sediments, with what are probably interbedded tuffs or lavas, and intersecting dykes of later age. The trend lines bear about  $80^{\circ}$  east of north.

### SILLIMANITE.

In the low cliffs of Lake Weelhamby immediately south of the amphibolite, cummingtonite schist and serpentine, which form the eastern end of the greenstone series, a cross section of sillimanite schist is exposed for a width of several chains. The rock is greyish white in colour, distinctly schistose with slightly silky lustre, and in places dotted with a few red garnets. It is somewhat porous from the weathering and partial leaching of biotite, chlorite, and felspar. Under the microscope the rock is seen to be composed of coarsely granular quartz with dense bundles of sillimanite fibres lying parallel to the schistosity and often penetrating the quartz grains. An occasional garnet is visible, and some finely granular sericite with a weathered intergrowth of biotite and muscovite, and granular black and brown iron ore. Some of the sillimanite was separated by means of methylene iodide, and proved to possess the characteristic optical properties.

A few chains inland a much denser, and almost completely unweathered, sillimanite quartzite was collected. The microscope discloses a coarse mosaic of quartz on which are superimposed numerous bundles and isolated needles of colourless to light brown sillimanite ; these do not interrupt the structure of the quartz mass, but penetrate it in every direction. There is an appreciable parallelism of most of the bundles, but others are arranged in radiating groups, or set at various small angles to the direction of schistosity. Small flakes of brown biotite are present, and at rare intervals a granular aggregate of andalusite, showing a colourless to pink pleochroism.

About a mile and half further west a dense dark grey rock was found which showed small silky patches of white sillimanite on the faces of fractures. A section showed the rock to be a granular quartzite with plentiful sheaves and isolated fibres of sillimanite. A fair proportion of the sheaves show a broad and apparently structureless centre, with terminal

† Ibid, p. 874.



proliferation into fine spicules. Under high magnification and crossed nicols the centres of these masses prove to be finely fibrous. Scales of biotite are present, with an occasional scale of chlorite or crystal of garnet. Granular black iron ore is plentiful.

#### ANDALUSITE.

In addition to the small quantity of andalusite mentioned above as occurring in specimens of sillimanite schist, there are long narrow lenses of andalusite-muscovite schist interbedded in the sediments. One such occurs close to the east end of the range where the outcrop is covered by many loose boulders of the rock showing abundant andalusite individuals projecting from the scaly micaceous surface. The andalusite in these is sub-angular, the individuals averaging about one centimetre in length. They are subvitreous, of a dark brown colour, and show no signs of chistolite structure. One band in this mass is less plainly micaceous, and is grey in colour from the presence of finely divided carbon, with which the andalusite itself is saturated.

About two miles to the south-west another band of carbonaceous andalusite schist is exposed on the outermost slopes of the hills. This is very much weathered, and the andalusite weathers out in hard, dark grey carbonaceous lenses about one centimetre long.

In a creek between the two places mentioned, large angular pebbles of pure crystalline andalusite were found. These were traced to two highly quartzose pegmatite veins traversing hornblende schist near the crest of the ridge. The two veins were only a short distance apart and the portions of the outcrops in which andalusite was visible were only about a chain in length. In the outcrops andalusite was lying loose on the surface, or projecting from the quartz, in masses weighing from something under a kilogramme to 25 kilogrammes (50 lbs.). Masses over five kilos were quite common. They were slightly divergent groups of coarsely prismatic crystals, none of the latter being sufficiently clearly developed to afford angular measurements. They were mostly of a deep purple colour, but even in the one mass the colour often ranged from light vinaceous grey (Ridgway 69<sup>f</sup>) to anthracene purple (69<sup>k</sup>), the lighter portions forming vertical streaks in, or outer borders to, the large masses. The accompanying Plate XVII. shows typical specimens of the mineral. A similar occurrence is described by Calderon at Montalban, Toledo, Spain.\*

One of the darker coloured pieces was selected for analysis and gave the following results:—

#### ANDALUSITE, NINGHANBOUN HILLS.

SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	Mn <sub>2</sub> O <sub>3</sub>	Ti <sub>2</sub> O <sub>3</sub>	H <sub>2</sub> O +	Total.	G.	N.
36.06	60.80	1.61	trace	.11	.94	99.52	3.13	1.643, 1.638, 1.632

(Analyst: H. P. Rowledge.)

Examination of the powder revealed a straight extinction with normal optical sign and pleochroism, viz. :—X, magenta; Y, Z, colourless.

A special search was made for manganese in the mineral in view of its purple colour, but only a faint trace of that element could be detected. The colour appears therefore to be due to the iron and titanium.

\* Calderon: Los Minerales de Espana, II., p. 321, Fig. 142.



### (3) CUMMINGTONITE (KUPFFERITE), NINGHANBOUN HILLS, S.W. DIVISION.

Cummingtonite has been defined as a monoclinic amphibole midway in composition between kupfferite ( $\text{H}_2\text{Mg}_7\text{Si}_8\text{O}_{24}$ )\* and grunerite ( $\text{H}_2\text{Fe}_7\text{Si}_8\text{O}_{24}$ ). Strictly speaking, therefore, all cummingtonite is either a ferruginous variety of kupfferite or a magnesian variety of grunerite. Cummingtonite schist is an unusual type of metamorphic greenstone which has only been recorded from a comparatively few districts throughout the globe. The recent discovery by the writer of an outcrop of it in the Ninghanboun Hills appears, therefore, to be worthy of description.

At the eastern end of these hills it was found in the Archaean complex in a narrow belt lying between serpentine and amphibolite on the one side, and andalusite schist and sillimanite schist on the other. A continuous band, or more probably a series of lenses, of this rock extends for about two miles in a westerly direction parallel to the boundary of the greenstones and meta-sediments.

The rock is pale to medium grey on fresh fracture, and cream coloured, or sometimes reddish, on the slightly weathered surface. In specimens collected near the east end of the hills, innumerable spicules of colourless to pale grey cummingtonite are plainly visible on fractures or weathered surfaces. These are oriented in different directions within the planes of cleavage. A section shows a rather finely granular base of plagioclase, sometimes singly or multiply twinned, in which are set the prismatic crystals of the amphibole. Several crystals twins and grains of transparent orange rutile were observed in the section as well as a little black iron ore, probably chromite.

An analysis of the fresh rock showed :—

#### CUMMINGTONITE SCHIST, NINGHANBOUN.

$\text{SiO}_2$	$\text{Al}_2\text{O}_3$	$\text{Fe}_2\text{O}_3$	$\text{FeO}$	$\text{MnO}$	$\text{MgO}$	$\text{CaO}$	$\text{K}_2\text{O}$
57.40	12.88	.93	8.02	.16	11.73	5.23	.24
$\text{Na}_2\text{O}$	$\text{TiO}_2$	$\text{Cr}_2\text{O}_3$	$\text{P}_2\text{O}_5$	$\text{H}_2\text{O} +$	$\text{H}_2\text{O} -$	Total.	G.
2.06	.45	.24	.11	1.42	.06	100.93	2.86

The analysis suggests a mixture of about 44 per cent. of labradorite with 55 per cent. of cummingtonite. In the latter lime is only present in traces whilst the ratio of Mg to Fe is 26 to 10. The Ninghanboun mineral is, therefore, a ferruginous kupfferite.

Some of the cummingtonite was separated with  $\text{CH}_2\text{I}_2$  from the crushed rock, and its physical properties determined. The prisms are usually 0.5 to 2.0 mm. in length and 0.02 to 0.30 mm. in diameter. The specific gravity is 3.04, and the crystalline system is monoclinic, prisms in one

\* Recent research indicates that the original kupfferite is a chromiferous actinolite, but the name has now come to connote the monoclinic lime-free amphibole. See A.J.S. 21 (1931, p. 343).



position showing a straight extinction, in others giving an angle with the vertical axis reaching a maximum of 17 degrees. The refractive indices determined by immersion were Ng 1.660 (at 17° with *c*), and Np 1.636 : Ng-Np, 0.024. The type mineral from Massachussets is a magnesian grunerite in which the ratio of Mg : Fe is 10 : 19. The graph in Winchells Elements of Optical Mineralogy indicates the following data for typical cummingtonite with Mg : Fe = 1 : 1. G, 3.27 : N, 1.673, 1.659, 1.645 : Ng-Np, 0.028. Angle between Z and *c*, 14 to 20°. Sundius' graph in the American Journal of Science (Vol. 21, p. 338) indicates for the same compound, G, 3.28 : N, 1.676, 1.658, 1.647 : Ng-Np, 0.029.

#### (4) DRAVITE, DARLING RANGES, S.W. DIVISION.

Recent investigations by the Author in conjunction with Mr. J. E. Wells have indicated the probable wide distribution of dravite (magnesia tourmaline) in the western portion of the Darling Ranges to the east and south-east of Perth. The Ranges in this area consist of granite, criss-crossed by epidiorite dykes and fault planes, and enclosing narrow bands of mica schist, which may be shear zones of the granite or roof pendants of the Precambrian schists, as these appear in an almost continuous, narrow, belt along the western foothills of the range.

Dravite is especially plentiful at Swan View, moderately so at Karra-gullen, and occurs to an undetermined extent at Kelmscott and between Mundijong and Jarrahdale. In addition schorl has been detected in small quantities at Gosnells and Cardup.

##### SWAN VIEW.

About a mile and a half north of the railway station attention was attracted by the peculiar appearance of some of the local granite. Parts of it are covered on the weathered surface with innumerable grey "warts," and other parts, having a comparatively smooth surface, are dotted with distinctly blue or grey spots. Microscopic examination proves that both peculiarities are due to aggregations of minute spicules of dravite. The grey "warts" are mostly three to five mm. in diameter, and consist of a mass of minute radiating prisms which are colourless under the microscope, and possess all the characteristics of dravite. The blue or grey spotted granite has been found to have had all its components, except the quartz, almost completely replaced by a spicular dravite, varying from a colourless variety to one which is light blue in mass, but mostly colourless in thin section, or rarely possessing a pale dichroism, E colourless, O greyish blue. A radial grouping of the spicules is extremely common, the diameter of individual crystals varying from 0.01 to 0.06 mm. In some specimens of the rock the radial fibres are plainly visible to the unaided eye, in others they can be readily detected with a low power lens. But in some the structure is so finely fibrous and compact as to be obscure even under the microscope, except between crossed nicols. This tourmalinised granite is abundant over an area of about 0.2 hectare (half an acre). In this area some of the joints in the granite are filled with a dense mass of bluish grey dravite five to ten mm. thick, which under the microscope proves to be composed of a felted mass of needles, many of them in radial groups, and colourless to pale blue in the direction of O.



Further search of the locality has revealed at a short distance to the west a slightly porous vein, 30 cm. (12 inches) thick, of almost pure, pale grey dravite. Microscopic examination discloses the same interlocking radial groups of colourless spicules, associated with a little greatly weathered chlorite or biotite. Some of the pure mineral from this vein was separated by methylene iodide and analysed, with the results given below. It is a typical dravite in composition, and chemical and physical properties.

Less than a kilometre (say half a mile) further to the north-east a similar but larger vein was discovered in a narrow band of mica schist flanked by granite. This vein bears  $55^\circ$ , and is about 60 cm. (2ft.) wide. It is less porous than the first vein, and paler in colour, almost white in places, mottled with dull green chlorite, etc. Under the microscope it is seen to consist mainly of a similar mass of colourless dravite spicules, accompanied by patches of partly weathered biotite, chlorite, muscovite, kaolin, and limonite.

Mr. Wells has followed the strike of this vein and secured specimens of dravite at intervals for about another two kilometres (1.25 miles). Altogether in this area many tons of dravite must be exposed at the surface.

#### KARRAGULLEN.

Crossing Black Adder Creek and the Dale Road five miles south-east of Karragullen railway station are two parallel veins composed of a mixture of quartz and dravite, the latter in large excess over the former. The ground is much obscured by soil and lateritic gravel, but sufficient outcrops can be seen in the vicinity to show that the veins are in granite in close proximity to an epidiorite dyke. They strike approximately east. No continuous outcrop can be traced, but only a series of large masses of the vein-filling, projecting at intervals from the soil, and in one place from the bed of the creek. From the appearance of these the veins must be about a metre (3 feet) in width.

Material collected from the outcrops is of three types. (A) A mixture of white quartz and white dravite in which the latter is just visibly seen to be spicular in form, and frequently grouped in radiating masses. From such material pure dravite was separated by  $\text{CH}_2\text{I}_2$  and analysed (see below). Under the microscope the mineral is seen to be in perfectly transparent colourless prisms, with straight extinction, high birefringence and negative elongation. Individual prisms range up to four mm. in length but are usually only 0.02 to 0.10 mm. in diameter.

(B) A second type looks like a finely granular white quartzite. Slices under the microscope reveal a dense intergrowth of small stout prisms of colourless dravite with a small percentage of quartz in the form of archipelagoes of interstitial fillings.

(C) Most plentiful is a dense pale grey mass of dravite with no structure in the main mass visible to the naked eye, but including veinlets and geodes of distinctly spicular nature. A slice of this dense rock reveals under the microscope a structure practically identical with B, the dravite being colourless and in the form of grains and prisms averaging 0.1 mm. in diameter, without any regular arrangement, either radial or parallel.



## DRAVITE, DARLING RANGES.

—				Karragullen.	Swan View.	Jarrahdale.	Kelmscott.
SiO <sub>2</sub>	...	...	...	38.30	36.57	36.80	36.14
Al <sub>2</sub> O <sub>3</sub>	...	...	...	36.99	35.01	37.14	29.98
Fe <sub>2</sub> O <sub>3</sub>	...	...	...	trace	trace	.18	?
FeO	...	...	...	.22	1.12	1.80	10.50*
MnO	...	...	...	.01	.01	trace	trace
MgO	...	...	...	8.90	11.40	8.33	6.78
CaO	...	...	...	Nil	.37	.11	1.16
Na <sub>2</sub> O	...	...	...	1.88	1.39	1.60	...
K <sub>2</sub> O	...	...	...	Nil	.25	.08	...
Li <sub>2</sub> O	...	...	...	.16	Nil	Nil	...
H <sub>2</sub> O+	...	...	...	3.55	4.46	4.48	...
H <sub>2</sub> O—	...	...	...	Nil	Nil	.10	...
TiO <sub>2</sub>	...	...	...	.15	.36	.18	.52
B <sub>2</sub> O <sub>3</sub>	...	...	...	10.38	9.78	9.63	...
F	...	...	...	.07	n.d.	n.d.	...
				100.61	100.72	100.43	n.d.
Analyst	...			Murray	Simpson	Rowledge	Grace
MgO : FeO	...	...	...	737 : 10	177 : 10	83 : 10	11 : 10
G	...	...	...	3.03	3.03	3.03	3.07
No	...	...	...	1.634	1.635	1.636	1.658
Ne	...	...	...	1.612	1.612	1.614	1.632

\* Total iron expressed as FeO. The figures for the refractive indices, determined by the immersion method, illustrate the rise in these figures with increase of iron.

## JARRAHDALÉ.

A number of specimens of dravite have been brought to me from an ill defined spot between Mundijong and Jarrahdale, which are five miles apart. They consist of a fairly dense and tough bluish grey rock, which on close inspection is found to be an agglomeration of spherical masses of radiating needles of dravite. The composition of the carefully purified mineral is shown in the table above. The spherical masses are mostly five mm. in diameter, whilst the fibres of which they are composed are 0.02 to 0.1 mm. in diameter and two to three mm. long. Under the microscope they are either colourless in both directions, or E is colourless, O pale blue. In hand specimens the centres of the radial masses are either white or almost so, the colour deepening in passing outwards through Ridgways gull grey to deep gull grey.

This occurrence has not been inspected by the Author, but it is probable that the mineral is in veins in granite or gneiss as at Swan View and Karragullen.

## KELMSCOTT.

About 1913 the late A. J. Robertson, a member of the Author's staff, collected what is probably a unique specimen of dravite in the ranges near Kelmscott. Unfortunately the exact locality was not recorded at the time, and has not been rediscovered. This specimen represents a vein 4.5 cm. (1.75 in.) wide filled with what, but for its colour, would be taken for "cross fibre" asbestos. Analysis proves that the mineral, which completely fills the vein, is a ferruginous dravite (see partial analysis above). It is in long, very narrow (0.01 to 0.03 mm.) fibres extending inwards from either wall, and meeting at the centre line, where owing to dislocation of the walls, the axes of the fibres take an S form. The only associated mineral is quartz which occurs in thin discontinuous masses on the walls of the vein.

## (5) GAHNITE, GREENBUSHES, S.W. DIVISION.

As long ago as 1907 the Writer recognised gahnite in alluvial tin ore from Greenbushes and recorded its occurrence in Geological Survey Bulletin 30. In Bulletin 32 (1908), H. P. Woodward published a table showing the results of a mineralogical investigation by the present Writer of a number of typical Greenbushes concentrates, all from alluvial ground. This shows the existence of gahnite as a minor constituent of dressed tin ore from Spring, Floyd's, Elliott's, and Battler Gullies, all arising in the high ground surrounding the town. In the Writer's experience it was most plentiful in Spring Gully, to the west of the town, where it was associated with kaolin, quartz, cassiterite, ilmenite, zircon, rutile, magnetite, garnet, kyanite, and limonite. An old Greenbushes tin miner says, however, it was still more abundant in Bunbury Gully and other places at the south end of the field.

The only record of its occurrence *in situ* is that by F. R. Feldtmann and R. A. Farquharson\*, who observed it in lodestuff (albite pegmatite) in the Kapanga tin mine (M.L. 515), where it is associated with albite, quartz, schorl, cassiterite, and garnet.

In the concentrates examined, gahnite occurs either in rounded grains, or in well defined octahedra. No crystal faces other than those of the unit octahedron have been observed. In size the individuals range from 0.5 to 5.0 mm., and in colour from almost colourless through various shades of green to greenish black. The usual size is about two mm., and the commonest colour celadine green (R33<sup>4b</sup>). Under the microscope the mineral is translucent to transparent, and isotropic. The refractive index, determined for me by Mr. H. Bowley by immersion in matured mixtures of piperine and iodides, is  $1.818 \pm .005$ . Its specific gravity varies from 4.55 to 4.58.

An analysis was recently made of a carefully selected parcel of grains of uniform celadine green colour. The results are:—

## GAHNITE, GREENBUSHES.

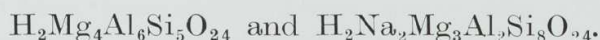
—	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	Cr <sub>2</sub> O <sub>3</sub>	FeO	MnO	ZnO	MgO	CaO	SiO <sub>2</sub>	Total.	G.	N.
Per cent.	53.73	2.53	Nil	1.72	.50	41.66	Nil		.70	100.83	4.57	1.818
Mols ...	527	16	—	24	7	512	—		12			

## (6) GEDRITE, BULLSBROOK, S.W. DIVISION.

Gedrite is an uncommon aluminous variety of anthophyllite, not previously recorded in the State. Normal anthophyllite has the composition:



Gedrite is a cocrystallisation of one or more aluminous molecules with the above, possibly—



In both varieties ferrous iron usually displaces part of the magnesia.

The Bullsbrook mineral occurs in the Archaean complex in a coarse gabbro pegmatite composed of gedrite and an undetermined plagioclase with

\* G.S.W.A., Bull. 59, pp. 166, 169.



a little microscopic rutile. It is in long "deep slate green" (R33k) prisms up to several centimetres in length and one in width. There is a marked prismatic cleavage with a prism angle of approximately  $60^\circ$ . The specific gravity is 3.16, and the refractive indices are 1.659, 1.653, 1.643. Ng-Np, 0.016.

The extinction is straight in the prism zone and elongation positive. Considering the deep colour of the mineral in mass it was strange to find that under the microscope the powder is almost colourless; even in fragments 0.1 mm. thick the absorption is slight, the pleochroism being colourless to pale smoke brown or greenish brown, with the maximum absorption parallel to Z. This absorption, however, is much more pronounced when the thickness reaches 0.3 mm., at which the pleochroism is pale greenish yellow to greenish brown.

Material for analysis was obtained by separation with methylene iodide, and was checked for homogeneity with the microscope. The original analysis yielded 2.96 per cent. of  $\text{TiO}_2$ , but separation with HF plus  $\text{H}_2\text{SO}_4$  and microscopical examination, showed that this was present as crystallised rutile. The composition, which is very close to that of the type mineral from Gèdres in France, is:—

## GEDRITE, BULLSBROOK AND GEDRES.

—	$\text{SiO}_2$	$\text{Al}_2\text{O}_3$	$\text{Fe}_2\text{O}_3$	FeO	MnO	MgO	CaO
Bullsb Brook...	45.38	14.70	.94	18.14	.31	15.26	.62
Gèdres ...	42.86	16.52	...	18.82	...	15.51	1.90

—	$\text{Na}_2\text{O}$	$\text{K}_2\text{O}$	$\text{H}_2\text{O}$ —	$\text{H}_2\text{O}$ +	Total.	G.	N.
Bullsb Brook...	1.20	.19	.23	2.77	99.74	3.16	1.659, 1.653, 1.643
Gèdres ...	...	...	...	4.50	100.11	...	(E.S.S.)

Analyst: D. G. Murray.

The Bullsb Brook mineral represents a cocrystallisation of the following molecules:—

Anthophyllite	...	$\text{H}_2(\text{Mg}, \text{Fe})_7\text{Si}_8\text{O}_{24}$	...	69.0 per cent.
(Unnamed)	...	$\text{H}_2\text{Mg}_4\text{Al}_6\text{Si}_5\text{O}_{24}$	...	20.5 "
Glaucophane	...	$\text{H}_2\text{Na}_2\text{Mg}_3\text{Al}_2\text{Si}_8\text{O}_{24}$	...	10.5 "

## (7) LECHATÉLIERITE, WEST POPANYINNING, S.W. DIVISION.

Lechatelierite is the name given by A. Lacroix in 1915\* to naturally occurring silica glass, his original paper describing its occurrence in quartzose xenoliths in lavas, and in fulgurites, the latter found both in loose sand and in acid rocks such as granite and siliceous schists. A third mode of occurrence has been described by A. F. Rogers † in the sandstones surrounding the meteor crater near Canyon Diablo, Arizona, where it is supposed to have formed as the result of the high temperature following the impact of an immense meteor on hard sandstone.

Fulgurites, the fused tubes formed by lightning when an exceptionally powerful current strikes dry sand or soil, are composed mainly of lechatel-

\* Bull. Soc. Franc. Min. 38, pp. 182, 188.

† Am. Miner. 13, pp. 77, 82.



ierite, and are known to be present amongst the sand dunes near Sydney, not to mention many foreign localities. Up till now they have remained undiscovered in Western Australia.

On 6th April, 1931, Mr. G. E. Watts, of West Popanyinning, had the good fortune to observe the formation of a fulgurite. During the course of a severe thunderstorm he saw a violent flash of lightning strike some sandy ground about 400 yards away, and thereafter smoke or steam rising from the ground where it was struck. On investigation he found the ground blackened and still hot over an area about 20 cm. (8 inches) in diameter, and digging revealed a vertical core of lechatelierite in the soil. This core was hollow and very brittle, and extended downwards for about a metre (approximately 3 feet), small branches radiating from it at several points.

Through the courtesy of the Government Astronomer (Mr. H. B. Curlew) and the Curator of the Museum (Mr. L. Glauert) I have been enabled to examine in detail a number of short sections of the fulgurite. The soil in which it was formed is a cream or buff coloured, somewhat clayey and felspathic sand. The cross section of the central hollow is very variable, in places almost round, in others lenticular or angular, with wing-like extensions throughout, which give rise to a two, three, or four rayed section, narrow hollows extending practically to the ends of the rays. This hollow structure appears to be due to the expansion of steam at the time of formation. The form at various depths is illustrated in Plate XVII., Fig. 2.

The thickness of the fused lining is mostly 0.5 to 1 mm. and nowhere exceeds 2 mm. On the outer surface it is dull and rough from adherent sand and clay, but the inner surface is brilliant and glassy with a minutely mammilated structure. In colour this surface is greyish white and translucent, but small areas are darkened by the presence of iron silicate, etc.

Some of the cleanest fragments were lightly crushed to pass a 60-mesh sieve, and vanned to remove fine clay particles. After drying, the remainder was separated into several fractions by means of methylene iodide mixed with xylol. The fraction having a specific gravity between 2.20 and 2.22, was proved by the microscope to be pure lechatelierite. It was almost wholly colourless, the few darker grains proving to owe their appearance to plentiful inclusions of gas bubbles from which much of the material was entirely free.

Optical examination proved the separated mineral to be isotropic. Its refractive index was determined by immersion in a mixture of alboline and kerosene. In a mixture having a R.I. of 1.465 some of the grains were found to have an identical index, about one-third of them had an index slightly higher, and an equal number were slightly lower than the medium. *N* may, therefore, be taken at 1.463 to 1.467, figures slightly higher than that given by A. Lacroix for the natural mineral of high purity, viz., 1.4585. The density too is slightly greater than that of pure fused silica which is 2.205.

Analysis explains this increased refraction and weight, the Popanyinning glass containing a considerable proportion of metallic oxides which must also materially lower the melting point below that of pure silica. The figures obtained were:—

LECHATELIERITE, WEST POPANYINNING.

SiO <sub>2</sub>	TiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	MnO	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	Total.	G.	N.
88.46	.46	6.69	1.16	trace	.17	.17	.01	2.68	99.80	2.21	1.465



## (8) PYROLUSITE, COPPERMINE CREEK, S.W. DIVISION.

A little desultory mining has been done for many years past on a number of manganese lodes running approximately east and west across the valley of Coppermine Creek to the east of the Fitzgerald River. The lodes occur in a complex of greenstones and schists of Precambrian Age. Most of the ore discovered has been a dense structureless, or slightly cellular, mixture of pyrolusite and psilomelane with more or less limonite. Small patches of highly crystalline ore were, however, met with, and one such has been subjected to detailed examination. This ore appears to have grown from the sides of cavities in a mamillary layer, or series of layers, each composed of bundles of imperfectly developed prismatic crystals at right angles to the surface of the cavity. The colour is black, lustre brilliant, specific gravity 4.58 and hardness 2. The composition of carefully handpicked material was:—

## PYROLUSITE, COPPERMINE CREEK.

MnO <sub>2</sub>	MnO	NiO	Co <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	BaO	CaO	MgO	CuO	
92.52	2.33	.07	.65	.25	.15	.13	.02	.17	.12	
PbO	Na <sub>2</sub> O	K <sub>2</sub> O	H <sub>2</sub> O +	H <sub>2</sub> O—	TiO <sub>2</sub>	CO <sub>2</sub>	SiO <sub>2</sub>	SO <sub>3</sub>	Total.	G.
<i>Nil</i>	.06	.06	1.59	.64	<i>Nil</i>		.66	.02	99.44	4.58

(Analyst: H. P. Rowledge.)

The data indicate that the crystalline mineral is a pseudomorph after manganite, composed mainly of pyrolusite, but intimately mixed with a little residual manganite and secondary psilomelane.

## (9) STILBITE, GOOSEBERRY HILL, S.W. DIVISION.

Half-way up the railway zigzag on the face of Gooseberry Hill, is the large quarry from which the Perth City Council draws its supplies of epidiorite and granite for ballasting roads and making concrete. On the south-east side of the quarry the eastern wall of an epidiorite dyke is covered by a thin sheet of chloritic material in which from time to time lenses of stilbite have been found. These have a thickness of 0.5 (or even less) to 2.5 centimetres, with a vertical and lateral extension ranging from a few centimetres to about one metre. The lenses consist wholly of stilbite, or of a coarse grained mixture of stilbite and calcite.

The stilbite is always coarsely crystalline and occurs in tabular groups with fan-like structures, the perfect cleavage parallel to  $b(010)$  being distinctly visible. Occasional small vughs permit of the free growth and recognition of crystal faces, the usual combination being  $bcm$ , combined in the form of a double twin by reflection and rotation on  $c(001)$ . This is a common structure illustrated in the text-books.

The colour is a pinkish buff, ranging from Ridgway "13f" to "15d." It is translucent in layers of one to two mm. The specific gravity is 2.17.



An analysis made for me by Mr. J. N. A. Grace yielded the following figures, after deducting 0·64 per cent. of CaCO<sub>3</sub>.

STILBITE, GOOSEBERRY HILL.

—				Per cent.	Mols.	87 A + 13 B.
SiO <sub>2</sub>	...	...	...	57·38	955	59·0 %
Al <sub>2</sub> O <sub>3</sub>	...	...	...	15·67	154	15·1
Fe <sub>2</sub> O <sub>3</sub>	...	...	...	·15	1	...
CaO	...	...	...	7·46	133	7·8
MgO	...	...	...	·21	5	...
FeO,MnO	...	...	...	<i>Nil</i>	...	...
K <sub>2</sub> O	...	...	...	·18	2	...
Na <sub>2</sub> O	...	...	...	·56	9	·6
H <sub>2</sub> O+	...	...	...	16·67	926	} 17·3
H <sub>2</sub> O—	...	...	...	2·02	112	
P <sub>2</sub> O <sub>5</sub>	...	...	...	·04	...	
TiO <sub>2</sub>	...	...	...	<i>Nil</i>	...	...
				100·34	...	100·0
G	...	...	...	2·17		

The composition of a co-crystallisation of 87 per cent. of CaAl<sub>2</sub>Si<sub>6</sub>O<sub>16</sub>·6H<sub>2</sub>O with 13 per cent. of NaAlSi<sub>7</sub>O<sub>16</sub>·6H<sub>2</sub>O is given in column (3) for comparison.

DESCRIPTION OF PLATE XVII.

- Fig. 1.—Large masses of crystallised Andalusite, weighing four to 20 kilos., photographed on outcrop, Ninghanboun Hills. (Scale, one-tenth.)
- Fig. 2.—Lechatelierite (Fulgurite), West Popanyinning. A and B show wing-like extensions of the main tube, an oblique section of which appears on the left side of each specimen, from which all loose soil has been removed ; C, a lenticular section ; D, an approximately circular section from close to the surface ; E, F, and G show the fulgurite *in situ* in the compact soil, E at a considerable depth. (Natural size.)



## Plate XVII.



Fig. 1.

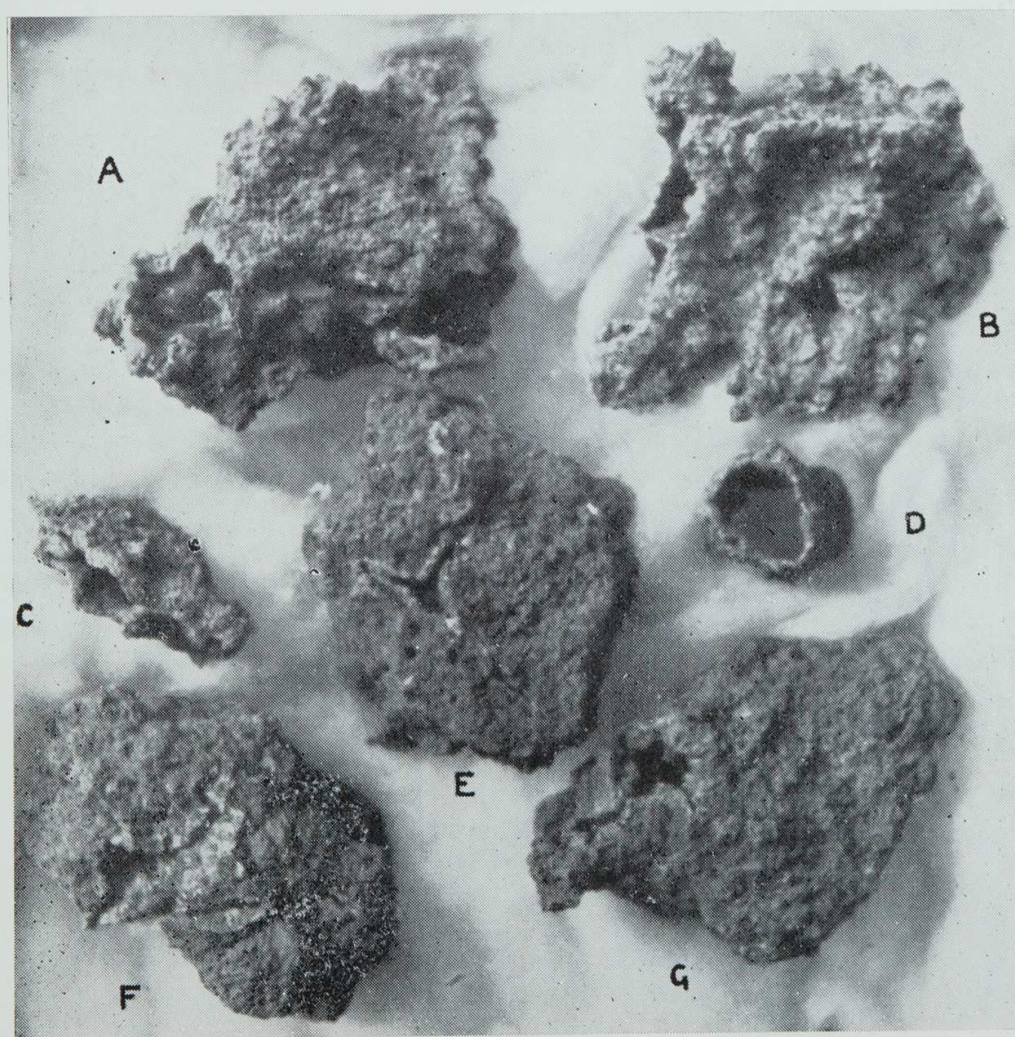


Fig. 2.



